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PROGRESS REPORT

August 20, 1973 - October 19, 1973

CROP IDENTIFICATION AND ACREAGE MEASUREMENT UTILIZING ERTS IMAGERY 013

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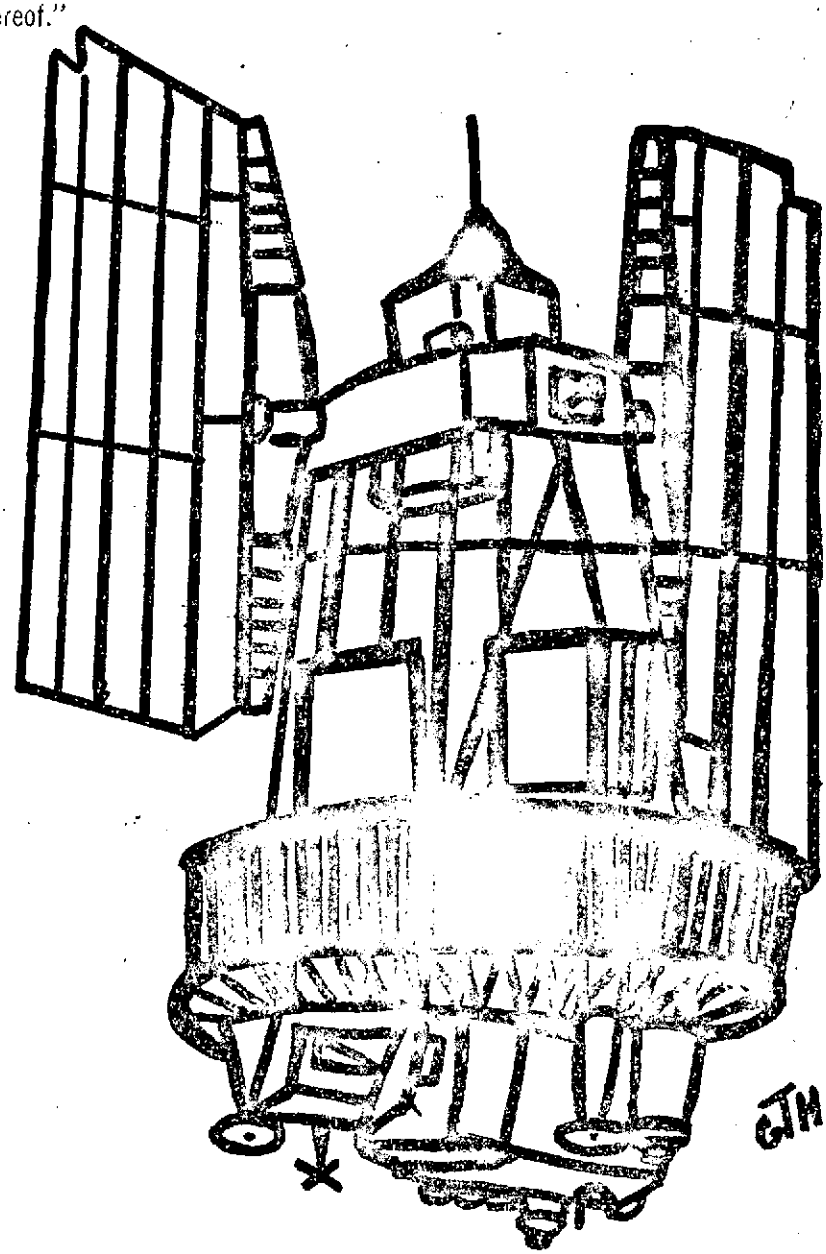

PRINCIPAL INVESTIGATOR

DONALD H. VON STEEN AG 328

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Microdensitometer

General

The microdensitometer has had some minor problems with the tape transport. However, these have been remedied and the microdensitometer has been used successfully.

Specifications for the aperture wheel and objectives, which we need, have been written and an order has been sent to the procurement officer. These items are necessary in our work.

Software Support

Microdensitometer to SAS

A program (PDSCMS) has been written to convert the microdensitometer scan picture into a SAS compatable form. The program is ready for testing and debugging, and is expected to be operational soon.

Basically it operates as follows:

(1) The microdensitometer produces a 2 dimensional scan picture.

(2) There is a scan picture for each color separation produced.

(3) A multivariate observation consists of combining corresponding elements from each scan picture.

(4) The basic microdensitometer record is a line of data points.

(5) A SAS observation is all values for a single pixel element.

The PDSCMS program takes corresponding elements from 1 to 4 scan pictures and produces SAS observations. In addition, the following house keeping functions are performed:

(1) The scan pictures are verified as being correct.

(2) The scan pictures must be compatable (same number of lines and elements).

(3) The scan raster may be removed.

(4) The user may assign up to 4 symbolic identifiers to each observation.

(5) The x,y coordinate position of each pixel is computed and included in the observation.

(6) A serial number is assigned to each pixel.

(7) Unused color values are assigned the missing value (-0)

Each SAS observation produced by PDSCMS has the following items:

SCENE-NAME	to identify the picture
PISECT-NAME	to identify the picture section
GROUP-NAME	classification group or blank
IDENT-NAME	user identified group or blank
XORD	X cordinate
YORD	Y cordinate
PSN	pixel serial number
PIXF1V	filter 1 reading for pixel
PIXF2V	filter 2 reading for pixel
PIXF3V	filter 3 reading for pixel
PIXF4V	filter 4 reading for pixel

By use of appropriate control cards the user is allowed to control the setting of the identifier names, the initial cordinate location, and initial serial number.

Microdensitometer to Penn State Classifier

A program is being designed to convert the microdensitometer scan data into a form which can be utilized by the Penn State Classifier directly. This program should facilitate the use of that classification system. In addition, the conversion program will be highly modular with disposable subroutines so that enhancements and new features can be added.

We are being assisted in this project by Tom Nichols, a programmer from the Systems Branch of the Statistical Reporting Service.

Penn State Classifier

Version II of the Penn State Classifier was wiped off the tape by the Washington Computer Center before a back-up copy could be made. We have requested and received a new copy from Dr. Borden at Penn State. An attempt to put up Version II will be made as time permits.

Ground Survey Observations

The ground survey observations have been summarized. The initial survey was conducted in June 1972. However, no data was collected during July, because of the uncertainty of ERTS's launch. The update observations and respective standard errors were computed for all major crops and land uses reported. In the following tables the major crops are shown by states.

Table 1--MISSOURI: Acreage estimates in ERTS study site from ground observations by month for select crops, 1972.

Crop \ Date	June			August			September			October		
	Estimate	Standard Error	C.V.	Estimate	Standard Error	C.V.	Estimate	Standard Error	C.V.	Estimate	Standard Error	C.V.
	Acres		%	Acres		%	Acres		%	Acres		%
Cotton	528,908	78,357	14.8	486,784	73,218	15.0	486,784	73,218	15.0	360,011	62,474	17.4
Corn	67,308	16,849	25.0	65,306	18,051	27.6	63,123	18,068	28.6	36,738	11,797	32.1
Winter Wheat	319,997	56,649	17.7	2,820	2,813	99.7	2,820	2,813	99.7	-	-	-
Winter Wheat*	-	-	-	-	-	-	-	-	-	48,493	20,561	42.4
Soybeans	759,198	144,117	19.0	1052,448	165,294	15.7	1046,807	165,754	15.8	1020,987	165,473	16.2
Grain Sorghum	16,559	8,308	50.2	17,286	8,432	48.8	17,286	8,432	48.8	11,646	7,217	62.0

* 1973 acreage

The coefficients of variation, (the standard error divided by the estimate times 100) for Missouri range from 14.8 percent to 99.7 percent. It is interesting to note how the estimates varied by month as planting and harvesting takes place. Winter wheat and soybeans illustrate the double cropping practice which is very common in Missouri. The winter wheat reflects one field which was not harvested.

Table 2—IDAHO: Acreage estimates in ERTS study site from ground observations by month for select major crops, 1972.

Crop \ Date	June			August			September			October		
	Estimate	Standard Error	C.V.	Estimate	Standard Error	C.V.	Estimate	Standard Error	C.V.	Estimate	Standard Error	C.V.
	Acres			Acres			Acres			Acres		
Corn	63,983	15,495	24.2	63,929	15,362	24.0	32,607	9,110	27.9	12,123	5,307	43.8
Barley	136,629	29,281	21.4	73,616	18,540	25.2	3,842	2,956	75.0	-	-	-
Winter Wheat	59,270	24,190	40.8	39,592	19,868	50.2	510	504	98.9	-	-	-
Winter Wheat*	-	-	-	-	-	-	-	-	-	8,873	4,037	45.5
Spring Wheat	20,211	6,211	30.8	19,224	5,762	30.0	2,600	1,369	52.7	1,274	922	72.4
Potatoes	49,288	17,490	35.5	48,477	17,488	36.1	48,338	17,479	36.2	7,327	4,055	55.3
Field Beans	101,069	20,836	20.6	102,904	21,884	20.8	45,767	12,856	28.1	7,683	3,474	45.2
Alfalfa	230,118	29,518	12.8	220,659	27,882	12.6	225,502	28,008	12.5	227,657	28,084	12.3
Sugar Beets	68,695	16,346	23.8	68,191	16,278	23.9	69,415	16,409	23.6	67,806	16,070	23.7
Mixed Grain	27,293	7,109	26.1	45,461	22,032	48.5	348	241	69.3	440	308	70.0

* 1973 acreage

Table 3--KANSAS: Acreage estimates in ERTS study site from ground observation by month for select major crops, 1972.

Crop \ Date	June			August			September			October		
	Estimate	Standard Error	C.V.	Estimate	Standard Error	C.V.	Estimate	Standard Error	C.V.	Estimate	Standard Error	C.V.
	Acres			Acres			Acres			Acres		
Corn	347,849	114,470	32.9	420,127	135,917	32.4	407,164	132,121	32.4	273,442	94,154	34.4
Winter Wheat	1435,362	229,965	16.0	19,204	13,885	72.3	-	-	-	-	-	-
Winter Wheat*	-	-	-	-	-	-	291,468	199,823	68.6	2111,707	458,270	21.1
Grain Sorghum	638,723	168,938	26.4	755,179	177,470	23.5	736,193	169,471	23.0	696,388	163,769	23.5
Alfalfa	136,018	55,375	40.7	115,330	44,472	38.6	114,632	43,994	38.4	111,751	43,192	38.7
Sugar Beets	11,262	11,211	99.6	11,262	11,211	99.6	11,211	11,211	99.6	11,261	11,211	99.6
Fallow	1643,081	274,249	16.7	2097,958	420,635	20.1	1824,046	248,501	13.6	321,400	89,726	27.9

*/ 1973 acreage

Table 4--SOUTH DAKOTA: Acreage estimates in ERTS study site from ground observations by month for select major crops, 1972.

Crop \ Date	June			August			September			October		
	Estimate	Standard Error	C.V.	Estimate	Standard Error	C.V.	Estimate	Standard Error	C.V.	Estimate	Standard Error	C.V.
	Acres			Acres			Acres			Acres		
Corn	957,449	98,744	10.3	947,272	101,201	10.7	942,467	100,559	10.7	858,267	92,184	10.7
Oats	539,315	66,785	12.4	111,660	37,787	33.8	-	-	-	-	-	-
Barley	81,434	28,820	35.4	15,696	12,757	81.3	-	-	-	-	-	-
Rye	28,392	12,817	45.1	9,755	7,215	74.0	-	-	-	-	-	-
Rye*	-	-	-	-	-	-	-	-	-	17,326	1,928	66.8
Spring Wheat	20,573	13,127	63.8	30,765	15,664	50.9	7,426	6,099	82.1	-		-
Soybeans	33,881	17,118	50.5	33,444	15,167	45.3	33,444	15,167	45.3	26,310	13,065	50.0
Grain Sorghum	29,848	13,158	44.1	33,051	13,772	41.7	11,502	5,923	51.3	11,066	5,923	53.5
Alfalfa	318,515	57,431	18.0	301,274	51,701	17.2	302,279	51,709	17.1	311,699	57,239	18.4
Other Hay	146,371	45,984	31.4	255,864	59,386	23.2	281,720	60,601	21.5	255,862	60,802	23.8
Fallow	291,854	50,598	17.3	192,963	37,458	19.4	190,924	36,820	19.3	185,683	36,365	20.0

* 1973 acreage

The previous tables show the precision possible with the present ground system for SRS Study Areas. The coefficients of variation range from about 10 percent to nearly 100 percent. The nearly 100 percent was for sugar beets in Kansas which are clustered in a small area within the Crop Reporting District. It is expected that ERTS imagery will be highly related to the ground observations, and a substantial gain in precision will be obtained in the study area by using ERTS imagery in the estimation procedure.

Cost Analysis

Cost of Ground Data

The cost of ground data can be broken into collection costs and summarization costs. The data collection costs include 1) pre-survey planning and materials preparation, 2) enumerator training schools, and 3) enumerator fieldwork. The summarization costs include 1) collection, edit, and keypunch time for Washington, D.C. and State Statistical Office personnel, and 2) programming and summarization costs. These costs, on a per segment basis, are as follows:

I. Data Collection

1) Survey Planning and Materials Preparation

Research and Development	
Salaries	$ 6.92
Travel costs (map Preparation salaries)	1.36
Programming Costs	
Salaries	4,38
Computer costs	6.49
	$19.15

2) Enumerators Training Schools

Instructors	
Salaries	$ 4.65
Travel	2.46
Enumerators	
Salaries	$ 2.73
Travel	1.08
	$10.92

3) Enumerators Fieldwork	
Salaries	$25.42
Travel	15.69
	$41.11
Total Data Collection Costs	$71.18

II. Data Summarization

1) Collection Edit and Keypunch Costs	
SSO Salaries	$13.01
Research and Development Salaries	35.14
	$48.15
2) Programming and Summarization Costs	
Salaries	$13.57
Computer Costs	6.61
	$20.18
Total Data Summarization Costs	$68.33
Total ERTS Ground Truth	$139.51

It should be noted that the above cost data are for the update work conducted in August, September, and October. The regular ongoing June Enumerative Survey (JES) costs are not comparable since in addition to observing and recording ground cover, the JES records crop intentions and livestock numbers. Recognizing this to be the case, it is acknowledged that Remotely Sensed data would need to be supplemented with ground survey work. Estimates of these costs can be derived to obtain time and mileage by segment. Mileage rates and hourly wages applied against the miles driven and hours worked together give a total cost estimate by segment. This comparison follows:

I. JES Fieldwork costs

A. Time

District	State	Time	#Segs.	$/hour
9	Missouri	6.42 hr/seg.	52	3.30
6	S. Dakota	4.80 hr/seg.	50	3.30
7	Kansas	8.93 hr/seg.	48	3.30
2	Idaho	5.75 hr/seg.	44	3.30
	Total		194	

Time cost per segment $21.36

B. Mileage

District	State	Miles	#Segs.	\$/mile
9	Missouri	99.98 m/seg.	52	.11
6	S. Dakota	80.86 m/seg.	50	.11
7	Kansas	136.81 m/seg.	48	.11
2	Idaho	82.85 m/seg.	44	.11
	Total Mileage Cost			
	Mileage cost per segment			\$11.03

C. Total Time and Mileage

Total time and mileage cost per segment \$32.39

II. Update Fieldwork costs (3 visits)

A.	Salaries	\$25.42
B.	Travel	15.69
C.	Total Time and Mileage (41.11/3 = \$13.70)	\$41.11

Total update time and mileage costs per segment per visit \$13.70

The difference between \$32.39 and \$13.70 represents the additional costs of \$18.69 needed to locate the June Segment Operators, secure crop intentions, secure livestock data and farm labor data. The ERTS Update fieldwork only included locating the segments and recording the crops present and their conditions. The operators were not contacted unless the enumerator could not view the fields from the road.

Aircraft Costs

We have not been able to obtain exact aircraft cost data to date, but Mr. Bernie Nolan of NASA has given the following estimate of aircraft costs:

For the U-2, the cost is \$2,150 per hour and the coverage is about 400 nautical miles per hour. Coverage is 14.8 nautical miles on a side per scene.

$$\text{Scenes per hour} = \frac{400}{14.8} = 27.03$$

$$\text{Cost per scene} = \frac{\$2,150}{27} = \$79.63 = \$80$$

or about $60 per segment.

The only solid costs we have been able to obtain for ERTS is the cost of purchasing the CCT's from Sioux Falls at $160 per ERTS scene. Our study areas require about three scenes to cover them at a cost of about $9 per segment. Our understanding is that the $160 does not include the cost of launching ERTS or the cost of maintaining the satellite in orbit. Another way to look at these costs are that coverage is required at least three times during a growing season which brings ERTS costs up to about $27 per segment.

A recent cost study conducted by NASA of putting satellites up and their operating costs may make it possible to compute a more comparable cost. We have not had privilege to this study to date.

Data Analysis

Analysis was continued on the data for the Missouri test site and was begun for Idaho.

In the analysis, the equality of the covariance matrices was checked first because this is essential for the linear discriminant analysis assumptions to be valid. A test presented in Morrison's Multivariate Statistical Methods, page 152, was used to test the within crop covariance matrices of ERTS data.

For the following example, August 26, 1972 imagery bands 4, 5, and 7 was used. The covariance matricesfor cotton, soybeans, and grass were tested. The test was conducted as follows. The null hypothesis states that the covariance matrices are equal.

H_0: $\Sigma_1 = \ldots = \Sigma_k$ K = 3 crop groups

H_1: $\Sigma_i \neq \Sigma_j$

Let S_i be an estimate of Σ_i based on m_i degrees of freedom.

$$S \text{ cotton} = \begin{bmatrix} 6.76 & 7.01298 & .4914 \\ 7.01298 & 11.0889 & -5.66433 \\ .4914 & -5.6643 & 39.69 \end{bmatrix}$$

$$S \text{ soybean} = \begin{bmatrix} 6.6049 & 8.3623 & .8265 \\ 8.3623 & 13.9876 & -6.3146 \\ .8265 & -6.3146 & 64.6416 \end{bmatrix}$$

$$S \text{ grass} = \begin{bmatrix} 5.6169 & 5.8416 & .7525 \\ 5.8416 & 9.7344 & -6.3398 \\ .7525 & -6.3398 & 40.3225 \end{bmatrix}$$

Now we form the pooled estimate of Σ.

$$S = \sum_{i=1}^{k} \frac{miSi}{\Sigma\, mi} = \begin{bmatrix} 6.5567 & 7.4436 & .6638 \\ 7.4436 & 12.1519 & -6.0189 \\ .6638 & -6.0189 & 50.2976 \end{bmatrix}$$

The statistic for the modified likelihood - ratio test is

$$M = (\Sigma mi) \ln |S| - \sum_{i=1}^{k} mi \ln |Si|$$

$$= 149.25$$

Next, we form the scale factor

$$C^{-1} = 1 - \frac{2P^2 + 3P - 1}{6(p+1)(k-1)} \left(\sum_{i=1}^{k} \frac{1}{mi} - \frac{1}{\Sigma mi} \right) = .99678$$

and MC^{-1} is approximately distributed chi-squared with degrees of freedom 1/2 $(K-1)p(p+1)$ as mi tends to infinity if H_0 is true.

$$MC^{-1} = 148.77$$

Thus we must reject the null hypothesis i.e. the data does not support the assumption that the covariance matrice are equal.

Therefore, the assumptions for linear discriminant analysis would not be met and better results would be attained if quadratic discriminant functions were used. We will generally use the quadratic approach in our analysis. However, it should be pointed out that upon close examination, the covariance matrices are very similar in many respects. Corresponding elements in the three covariance matrices are of at least the same order of magnitude and have the same sign. Under such conditions, it is possible to get acceptable practical results from a linear approach, but we must use caution. Similar tests were run for the September 14, 1972 data and results were the same. These tests will be run in all test states.

Table 5--Preliminary Classification of Idaho study area data using August 1972 data bands 4, 5, and 7 and unequal prior probabilities.

	No. of Samples	Percent Correct	Number of samples classified into											
			PEAS BEANS	HARV BEANS	BRLY	ALFALFA	CORN	FALOTH	IDLE	OHAY	PASTURE	SUGBTS	POTATOES	SPWH
Peas and Beans	579	14.5	84	45	1	31	0	0	0	0	327	89	2	0
Harvested Beans	784	71.1	13	562	45	8	0	0	0	0	152	4	0	0
Barley	1019	11.5	33	271	117	27	0	2	6	0	489	64	10	0
Alfalfa	1318	17.3	57	51	2	228	0	0	6	0	527	422	25	0
Corn	542	0.0	10	21	9	119	0	0	0	0	221	161	1	0
Fallow and Other	684	0.4	14	13	3	14	0	3	33	0	575	26	3	0
Idle	206	26.7	4	10	0	1	0	1	55	0	135	0	0	0
Other Hay	11	9.1	0	0	0	0	0	0	0	0	5	3	2	0
Pasture	1484	80.7	38	25	4	78	0	2	49	1	1197	83	8	0
Sugar Beets	527	76.5	12	6	1	43	0	0	6	0	46	403	10	0
Potatoes	533	10.1	29	2	1	80	0	0	0	0	89	278	54	0
Spring Wheat	111	0.0	3	48	3	5	0	0	0	0	49	3	0	0
Total	7798		297	1054	186	634	0	8	155	1	3812	1536	115	0

Overall Performance 34.7

It is obvious that many groups are very similar and, therefore, misclassified results are high. We will try combining several into groups based on similarity of the estimated parameters since these initial results indicate a number of crops are not distinct.

Abstract of Talks

Report Given on SRS Remote Sensing Research for Top USDA and NASA Management

This talk outlined the history of using remote sensing in the Statistical Reporting Service and the current ERTS investigation. The classification results to date as reported in the previous progress report were presented.

Report to Staff Meeting

Bill Wigton presented a summary of ERTS analysis at the Staff meeting of the Statistical Reporting Service on September 12, 1973. The ERTS system was briefly explained and discriminant analysis was explained. Results presented in the last progress report of temporal overlays and unequal prior probabilities were explained. Also, the importance of independent data for evaluation and improving the discriminant was pointed out.